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TECHNICAL NOTE

No. 996

NET HEAT OF COMBUSTION OF AN-F-28 AVIATION GASOLINES

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National Bureau of Standards

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SUMMARY

Experimental data on the heats of combustion and hydrogen contents of a number of aviation gasolines have been used in deriving a formula for computing net heat of combustion from (measured) gross heat of combustion. This formula appears to be sufficiently reliable for the purpose and has the advantage of making hydrogen determinations unnecessary.

The data on heats of combustion are presented in tabular form, and in graphs showing the relation between net heat of combustion and (1) hydrogen content, (2) aniline point, (3) API gravity, and (4) the product of aniline point and API gravity.

Data are given on the change in aniline point with time, and also the change resulting from the addition of xylidine.

INTRODUCTION

The work covered by this report was undertaken at the request of the National Advisory Committee for Aeronautics in order to determine a reliable method of estimating the net heat of combustion (1) when the gross heat of combustion is known, and (2) when the gross heat of combustion is not known.

MATERIALS INVESTIGATED

The samples of gasoline originally investigated in connection with this project included 29 production samples of AN-F-28 aviation gasolines submitted by individual refiners

at the request of the Petroleum Administration for War, and two other samples of experimental fuels which were widely used in cooperative tests. Recent measurements of heat of combustion have also been made on 26 other samples of AN-F-28 aviation gasolines from various refiners, and the data obtained on these fuels are included in this report.

The producers of the gasolines investigated, and the number of samples supplied by each are listed below.

Producer	Number of samples[a]
Abercrombie & Harrison Oil Co.	1
Atlantic Refining Co.	1 (1)
Gulf Oil Corporation	2 (2)
Humble Oil & Refining Co.	2 (1)
Lago Oil and Transport, Ltd.	2 (2)
Magnolia Petroleum Co.	4 (2)
Phillips Petroleum Co.	1 (1)
Richfield Oil Co.	1 (1)
Shell Oil Co.	4 (4)
Socony Vacuum Oil Co.	4 (3)
Standard Oil Co. of California	2 (1)
Standard Oil Co. of Indiana	2
Standard Oil Co. of Louisiana	4 (3)
Standard Oil Co. of New Jersey	2 (2)
Standard Oil Co. of Ohio	1 (1)
Sun Oil Co.	2 (1)
Texas Co.	3 (2)
Tidewater Association Oil Co.	1 (1)
Union Oil Co.	2 (1)
White Star Refining Co.	1 (1)
Unspecified	15 (1)

[a]The numbers in parentheses represent gasolines included in the original group of samples 1 to 31, inclusive (tables 1 and 3).

DATA AND METHODS OF TEST

The specific gravity, and distillation data on the 31 gasolines originally investigated are given in table 1. Table 2 gives values of gravity, aniline point, hydrogen content, observed gross and net heat of combustion for these gasolines, values of net heat of combustion calculated from

a relation (equation(5)), derived from the results of the present work, which expresses net as a function of observed gross heat of combustion, and values of net heat of combustion calculated from the relation between gross and net heat of combustion given in specification AN-F-28, amendment 3. Table 3 gives values of gravity, aniline point, observed gross and calculated net heat of combustion for the 26 samples whose hydrogen contents were not determined. Each value of gross heat of combustion given in tables 2 and 3 is the mean of two determinations which usually agreed within less than 0.05 percent, although in a few cases the difference was as much as 0.1 percent.

The aniline points were determined in accordance with A.S.T.M. Method D611-44T. The carbon and hydrogen contents of gasolines 1 to 31 inclusive were both determined by combustion analysis. Except as noted, the hydrogen, percent by weight, reported in table 2 is the mean value of percent hydrogen as determined from water formed in combustion, and 99.8 minus percent carbon determined from CO_2, the value reported agreeing with these values in general to about 0.1 or 0.2 percent hydrogen. (The value 99.8 assumes 0.2 percent nonhydrocarbon present from 4 ml/gallon of tetraethyl lead.)

The bomb colorimeter and accessory apparatus, and the method of calculating results on gross heat of combustion have been described (reference 1). Two different types of thin-walled glass bulbs, previously described (references 2 and 3), were used to inclose the gasoline samples to prevent loss by evaporation, so that the mass of sample burned could be accurately determined. No significant difference was found in the results obtained with the two types of bulbs. The gross heat of combustion at constant volume was measured at about 30° C. In order to permit comparison of the results with data on pure hydrocarbons, most of which are referred to 25° C, the values of Q_v (gross) at 25° C, which are given in table 2, were calculated from the observed values of 30° C, using the following values of specific heats:

Gasoline (liquid)	C_p = 2.1 j/g deg C
Oxygen (gas)	C_v = 20.82 j/mole deg C
Carbon dioxide (gas)	C_v = 28.08 j/mole deg C
Water (liquid)	C_p = 75.29 j/mole deg C

The amounts of water formed in combustion of gasolines 1 to 31, inclusive, were calculated from the values of (percent H) given in table 2. For the remaining gasolines the values of (percent H) used were calculated from a relation between Q_v (gross) and (percent H) derived from equations (1) and (4) given later. This relation between Q_v (gross) and (percent H) and the values of specific heats given above, have been used to calculate values of the constant A in the relation:

$$Q_v \text{ (gross, } 25^\circ \text{ C)} = Q_v \text{ (gross, } t^\circ \text{ C)} + A(t-25)$$

The values of A calculated in this way are as follows:

Q_v (gross) Btu/lb	A Btu/(lb)(deg C)
19600	1.12
19800	1.21
20000	1.30
20200	1.38
20400	1.47
20600	1.55

UNIT OF HEAT

The calorimeter was calibrated electrically and checked at intervals by burning standard samples of benzoic acid of known heat of combustion. Thus, the energy equivalent, or effective heat capacity, of the calorimeter, was evaluated in terms of international joules (watt-seconds) per degree centigrade. The temperature rise of the calorimeter was measured with a platinum resistance thermometer. The weight in air of the gasoline burned was measured in grams. The observed gross heats of combustion were obtained in terms of international joules per gram weight in air against brass weights. For conversion to Btu/lb, use was made of the international steam table calorie (IT cal) defined as 1 IT cal = 1/860 international watt-hour, and the relation 1 IT cal/g = 1.8 Btu/lb. These two relations yield the convenient conversion factor

$$1 \text{ int } \frac{j}{g} = \frac{860}{3600} \times 1.8 = 0.43 \text{ Btu/lb}$$

Thus, the unit of heat used in this report is the same unit used in all modern steam tables, for example, reference 4.

RELATION BETWEEN GROSS AND NET HEATS OF COMBUSTION

In order to meet Specification AN-F-28 a gasoline must have a net heat of combustion of at least 18700 Btu per pound. Amendment 3 of this Specification requires determination of heat of combustion by means of an "oxygen-bomb calorimeter" which yields gross heat of combustion at constant volume Q_v (gross). In order to obtain values of net heat of combustion at constant pressure Q_p (net) from the results of bomb-calorimetric measurements, it is necessary to use a conversion relation, for example, with all Q's in Btu/lb.

$$Q_p \text{ (net)} = Q_v \text{ (gross)} - 91.23 \text{ (percent H)} \quad (1)$$

Values of heats of combustion of pure compounds are usually reported as gross heats of combustion at constant pressure Q_p (gross) at 25° C. For comparison with the data on gasolines, values of Q_p (net) for pure compounds were calculated from the reported values of Q_p (gross) using the relation

$$Q_p \text{ (net)} = Q_p \text{ (gross)} - 93.87 \text{ (percent H)} \quad (2)$$

where the Q's are expressed in Btu/lb. The numerical values of the coefficients of (percent H) in equations (1) and (2) depend only on the molecular weights of H_2 and H_2O, and on the properties of water. Using H_2 = 2.016 and H_2O = 18.016 for molecular weights, and the value 1050.4 Btu/lb (reference 4) for the heat of vaporization of water at 77° F (25° C), there is obtained:

$$\frac{18.016}{2.016} \times 1050.4 = 9387 \text{ Btu/lb}$$

of hydrogen for the heat of vaporization of the water formed in combustion. Since the hydrogen content of the gasolines is expressed in percent by weight, the coefficient of (percent H) in equation (2) becomes 93.87.

When O_2 (gas) combines at constant pressure (or constant volume) with solid carbon, or with carbon in a solid or liquid compound, to form CO_2 (gas) there is practically no change in volume (or pressure). When O_2 (gas) combines at constant pressure with the hydrogen in a solid or liquid compound to form H_2O (liquid), there is a decrease in volume, and external work ($= pV/2$) is done on the system, where pV is the product of the pressure and the volume of the water formed if it is in the gaseous phase at the temperature to which the reaction is referred. The external work done in the constant pressure process is included in the heat of the reaction at constant pressure Q_p (gross) which is therefore greater than Q_v (gross) by the thermal equivalent of the work done $pV/2$. Using the values at 77° F given in reference 4,

$pV/2 = 29.53$ Btu/lb of water

$$\frac{18.016}{2.016} \times 29.53 = 264 \text{ Btu/lb of hydrogen}$$

From this it follows that

$$Q_p \text{ (gross)} = Q_v \text{ (gross)} + 2.64 \text{ (percent H)} \quad (3)$$

where the Q's are expressed in Btu/lb. Combining this relation with equation (2) yields the conversion relation (equation (1)). Equation (1) was used to calculate the "observed" values of Q_p (net) reported in table 2 for gasolines 1 to 31 inclusive, from the values of Q_v (gross) and (percent H) given in the table. Equation (2) was used to calculate values of Q_p (net) from values of Q_p (gross) at 25° C reported for pure hydrocarbons.

COMPARISON OF NET HEATS OF COMBUSTION OF GASOLINES AND HYDROCARBONS

A comparison of data on gasolines and hydrocarbons is shown graphically in figure 1. The data on n-paraffins and iso-paraffins were taken from references 2, 3, and 5. The points in figure 1 designated as representing data on iso-paraffins are for the 2,2-dimethyl isomers only, since the data for the other isomers all lie between those for the 2,3-dimethyl isomers and the corresponding n-paraffins. The data on aromatics and cyclics were obtained from recent unpublished measurements at the National Bureau of Standards and other laboratories. The data on pure hydrocarbons are believed to be more accurate than the data on gasolines. The straight line in figure 1 represents a reasonable mean relation between net heat of combustion and percent hydrogen. A similar relation was pointed out by Jones and Starr (reference 6) who reported measured values for Q_v (gross) and (percent H) on 19 gasolines. Their results were converted to Q_p (net) by means of relation (1), and the values obtained are plotted in figure 1.

CALCULATION OF NET FROM GROSS HEAT OF COMBUSTION

As shown in figure 1, the data on gasolines 1 to 31, inclusive, are in good accord with the data on pure hydrocarbons, and both sets of data indicate a fairly reliable linear relation between Q_p (net) in Btu/lb at 77° F and (percent H), namely:

$$Q_p \text{ (net)} = 15365 + 234 \text{ (percent H)} \qquad (4)$$

for gasolines composed essentially of hydrocarbons. Combining this equation with the conversion relation for 77° F, previously given

$$Q_p \text{ (net)} = Q_v \text{ (gross)} - 91.23 \text{ (percent H)} \qquad (1)$$

gives

$$Q_p \text{ (net)} = 4310 + 0.7195\, Q_v \text{ (gross)} \qquad (5)$$

which supplies a convenient method of obtaining Q_p (net) from a measured value of Q_v (gross).

It may be noted from table 2 that values of Q_p (net) calculated from equation (5) for the gasolines 1 to 31 inclusive differ from the observed values by amounts ranging up to 0.2 percent, the average difference being a little less than 0.1 percent. The values of Q_p (net) given in table 3 for gasolines 32 to 57, inclusive, were calculated from equation (5), since hydrogen contents were not determined for these gasolines. The values of net heat of combustion given in the last column of tables 2 and 3 were calculated from the equation given in Specification AN-F-28 (amendment 3); namely, net Btu/lb = 4525 + 0.7070 × gross Btu/lb.

RELATIONS BETWEEN NET HEAT OF COMBUSTION, API GRAVITY AND ANILINE POINT

The values given in table 2 for Q_p (net) calculated from equation (1), and values given in table 3 for Q_p (net) calculated from equation (5) are plotted in figures 2, 3, and 4, which indicate approximate linear relations between net heat of combustion and aniline point, API gravity, and the product of aniline point and API gravity, respectively. It is obvious from the figures that API gravity is not so good a criterion for net heat of combustion as either aniline point, or the product of aniline point and API gravity.

The straight lines in figures 2 and 4 are represented by the following equations which were derived by the method of least squares:

$$Q_p \text{ (net)} = 17727.7 + 8.494 \text{ (AnPt)} \qquad (6)$$

$$Q_p \text{ (net)} = 17992.0 + 0.09839 \text{ (AnPt–Gr)} \qquad (7)$$

where Q_p (net) is the net heat of combustion at constant pressure in Btu/lb and (AnPt) and (AnPt–Gr) are aniline

point in degrees Fahrenheit, and the product of aniline point in degrees Fahrenheit and gravity in degrees API, respectively. The standard deviations of the measured heats of combustion from values calculated from equations (6) and (7) are 24.4 and 23.8 Btu/lb, respectively. The respective correlation coefficients are 0.9657 and 0.9644. Thus there is little reason to choose between the two criteria in the case of the data under discussion. However, as the gravities are not ordinarily determined as precisely as in the present data, and as added error in this determination will increase the error of the estimated heat of combustion, it appears that the aniline point is a somewhat more reliable criterion of the net heat of combustion.

According to equation (6) an aniline point of 114.5° F corresponds to a net heat of combustion Q_p of 18700 Btu/lb. However, as is evident from figure 2 the actual heats of combustion do not follow this relation exactly. If it is desired that there shall be only 1 chance in 10 of the net heat of combustion being below 18700, then the minimum aniline point must be set at 119° F; for 1 chance in 100 the aniline point must be set at 122° F. According to equation (7) an aniline-gravity product of 7200 corresponds to a net heat of combustion Q_p of 18700 Btu/lb, and the values 7596 and 7821 for the product correspond to 1 chance in 10, and 1 chance in 100, respectively, that the net heat of combustion will be below 18700 Btu/lb.

A change of 50 Btu/lb in the minimum acceptable net heat of combustion requires a corresponding change of 5.89 degrees Fahrenheit in the minimum aniline point, or a change of 508 in the aniline-gravity product.

Values of Q_p (net) calculated from equation (6) for integral values of aniline point from 90° to 149° F are given in table 5. Values of Q_p (net) calculated from equation (7) for integral values of the aniline-gravity product in the range 5000 to 10400 are given in table 6.

EFFECT OF NONHYDROCARBONS ON NET HEAT OF COMBUSTION

Of some interest are the following approximate values:

Material	Q_p (gross) k cal/mole	Q_p (net) Btu/lb	Density g/ml
(a) $Pb(C_2H_5)_4$	[a]1487	7950	1.659 at 18° C
(b) $C_2H_4Br_2$	[a]282	2500	2.178 at 20° C
Ethyl fluid[b]	——	5890	1.85
Xylidine	1108	15590	——

[a]Values supplied by Ethyl Corporation

[b]Assumed to consist of 62 percent (a) and 38 percent (b) by weight.

Using the value 0.72 g/ml for the density of gasoline, and the values of density and heat of combustion given above for $Pb(C_2H_5)_4$, $C_2H_4Br_2$, and ethyl fluid, it has been calculated that the addition of the amount of ethyl fluid equivalent to 4.6 milliliters of $Pb(C_2H_5)_4$ per gallon of mixture, lowers the net heat of combustion of gasoline at constant pressure by 0.31 percent, and that the addition of xylidine lowers the net heat of combustion by 0.17 percent for each 1 percent by weight of xylidine added.

EFFECT OF TIME AND OF THE ADDITION OF XYLIDINE ON ANILINE POINTS

After the aniline points reported in table 2 had been measured, the National Bureau of Standards was requested to determine the effect on aniline point of the addition of

xylidine to aviation fuels. As about 6 weeks had elapsed since the original determinations of aniline points, new measurements were made on samples of a number of the fuels. Most of the values obtained were found to differ from the original values, as shown by the data given in the third column of table 4. The changes in aniline point in the 6-week period ranged from +0.4° to -1.1° F, the average change being -0.36° F. One percent xylidine was then added to each of the samples, after which new measurements of aniline points were made. The effect of the addition of 1 percent xylidine, as shown by the data in the fifth column of table 4, was a change in aniline point by amounts ranging from -0.9° to -1.6° F, the average change being -1.19° F.

Ten weeks after the original measurements of aniline points, new measurements were made on samples of fuels 4 and 7, to which no xylidine had been added previously. Three percent of xylidine was then added to each of these samples, and the measurements of aniline points were repeated. The results of these measurements, given in the fourth and sixth columns of table 4, show that the changes in aniline point for fuels 4 and 7 in a period of 10 weeks were -0.6° and 1.2° F, respectively, and that the addition of 3 percent xylidine resulted in changes of -4° and -3.1° F, respectively, for these two fuels. No investigation was made to determine whether the changes in aniline point with time were due to evaporation loss or to other causes.

CONCLUDING REMARKS

Values obtained for the net heats of combustion of 31 aviation gasolines, and values reported in the literature for pure hydrocarbons are reasonably well represented as a function of hydrogen content by means of the linear equation

$$Q_p \text{ (net)} = 15365 + 234 \text{ (percent H) Btu/lb}$$

When this equation is combined with the relation connecting gross and net heat of combustion and hydrogen content, there is obtained the relation

$$Q_p \text{ (net)} = 4310 + 0.7195\, Q_v \text{ (gross) Btu/lb}$$

which can be used to calculate net from measured gross heat of combustion when the hydrogen content is not known.

Values obtained for the net heat of combustion of 57 aviation gasolines were found to be a linear function of either the aniline point or the aniline point–gravity product. These linear functions are shown graphically and by means of tables.

National Bureau of Standards,
Washington, D. C., May 14, 1945.

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Table 1. Specific Gravity and Distillation Data on 31 Gasolines

Fuel No.	Sp. Gr. 60/60°F	Distillation, °F at % evaporated 10	40	50	90	End Point	Loss %
1	.7209	139	186	200	262	316	1.1
2	.7135	143	190	205	263	324	1.1
3	.7199	138	170	183	269	333	1.1
4	.7104	149	194	205	245	351	1.0
5	.7177	138	194	211	268	350	1.3
6	.7369	143	202	219	284	343	0.9
7	.7363	142	194	211	281	338	1.2
8	.7094	140	167	178	271	334	1.3
9	.7203	142	178	190	275	343	1.2
10	.7157	143	182	195	263	333	1.2
11	.7167	142	171	182	286	338	0.9
12	.7114	136	170	184	276	343	1.0
13	.7177	140	178	192	279	329	1.0
14	.7268	151	202	213	280	338	1.1
15	.7214	137	187	207	274	330	1.2
16	.7265	133	190	210	283	336	1.3
17	.7249	148	201	212	274	343	1.1
18	.7099	142	193	211	264	353	1.1
19	.7224	145	201	217	288	356	1.2
20	.7285	141	202	220	287	348	0.9
21	.7213	139	192	208	287	348	1.2
22	.7244	142	190	206	283	345	1.1
23	.7253	136	188	208	282	334	0.8
24	.7271	147	203	221	284	334	1.1
25	.7221	140	200	215	284	340	1.2
26	.7226	132	180	197	283	351	1.1
27	.7321	138	188	207	289	340	1.0
28	.7234	142	180	196	282	333	1.1
29	.7299	149	204	218	259	307	1.2
30	.7079	141	178	189	253	298	1.0
31	.7416	142	207	225	289	346	1.0

Table 2. Gravity, Aniline Point, Hydrogen Content, and Heat of Combustion of 31 Gasolines

Fuel No.	Gravity	Aniline Point	Aniline Gravity Product	Hydrogen Content	Heat of Combustion			
					Observed		Calculated	
					Gross	Net[b]	Net[c]	Net[d]
	°API	°F	°F×°API	%	Btu/lb	Btu/lb	Btu/lb	Btu/lb
1	64.8	121.3	7860	14.8	20121	18771	18787	18751
2	66.8	136.4	9112	15.2	20250	18863	18880	18842
3	65.1	123.8	8059	14.8	20152	18802	18809	18772
4	67.7	146.5	9918	15.7	20395	18963	18984	18944
5	65.7	135.0	8870	15.1	20254	18876	18883	18845
6	60.5	122.8	7429	14.7	20077	18736	18755	18719
7	60.7	108.3	6574	14.3	19913	18608	18637	18603
8	68.0	131.5	8942	14.9	20247	18888	18878	18840
9	65.0	127.2	8268	14.9 [a]	20191	18832	18837	18800
10	66.2	132.8	8791	15.2	20241	18854	18873	18835
11	65.9	126.1	8310	14.8	20191	18841	18837	18800
12	67.4	130.6	8802	15.0	20197	18829	18842	18804
13	65.7	127.0	8344	14.9	20170	18811	18822	18785
14	63.2	132.3	8361	14.7	20191	18850	18837	18800
15	64.6	120.0	7752	14.6	20049	18717	18735	18700
16	63.3	115.2	7292	14.2 [a]	19999	18704	18699	18664
17	63.8	127.8	8154	14.7	20171	18830	18823	18786
18	67.8	142.3	9648	15.5	20355	18941	18955	18916
19	64.4	127.4	8205	15.0	20171	18803	18823	18786
20	62.7	119.7	7505	14.3	20093	18788	18767	18731
21	64.7	127.2	8230	14.6	20145	18813	18804	18768
22	63.8	119.3	7611	14.5	20052	18729	18737	18702
23	63.6	115.9	7371	14.5	19997	18674	18698	18663
24	63.1	121.6	7673	14.6	20041	18709	18729	18694
25	64.5	120.9	7798	14.7	20135	18794	18797	18760
26	64.3	120.9	7774	14.5	20083	18760	18760	18724
27	61.8	113.0	6983	14.6	19999	18667	18699	18664
28	64.1	127.0	8141	14.6	20096	18764	18769	18733
29	62.4	118.2	7376	14.8	20058	18708	18742	18706
30	68.4	139.3	9528	15.3	20316	18920	18927	18888
31	59.3	102.9	6102	14.0	19835	18558	18581	18548

[a] Values of hydrogen content determined from weight of water formed on combustion. The sum of carbon and hydrogen percentages were 98.9 and 98.7 for samples 9 and 16, respectively, whereas 99.7 was the average for the other samples.

[b] Q_p(net) calculated from equation (1)

[c] Q_p(net) calculated from equation (5)

[d] Net heat of combustion calculated from the equation given in Specification AN-F-28, Amendment-3, namely

$$\text{Net Btu/lb} = 4525 + 0.7070 \times \text{Gross Btu/lb}$$

Table 3. Gravity, Aniline Point and Heat of Combustion of 26 Gasolines

Fuel No.	Gravity °API	Aniline Point °F	Aniline-Gravity Product °F×°API	Heat of Combustion		
				Observed Gross Btu/lb	Calculated Net [a] Btu/lb	Calculated Net [b] Btu/lb
32	62.7	111.9	7016	19986	18690	18655
33	63.4	116.1	7361	19944	18660	18625
34	63.6	109.9	6990	19990	18693	18658
35	66.0	128.9	8507	20162	18817	18780
36	63.5	118.0	7493	20027	18720	18684
37	64.2	120.4	7730	20086	18762	18726
38	63.9	120.7	7713	20049	18735	18700
39	59.9	100.4	6014	19843	18587	18554
40	63.6	121.8	7746	20067	18748	18712
41	65.9	131.2	8646	20183	18832	18794
42	63.9	116.2	7425	20054	18739	18703
43	61.3	109.8	6730	19954	18667	18632
44	66.2	126.5	8374	20159	18815	18777
45	63.2	113.5	7173	20014	18710	18675
46	65.1	127.2	8281	20178	18828	18791
47	61.3	111.2	6817	19960	18671	18637
48	62.1	109.9	6825	19936	18654	18620
49	61.2	110.1	6738	19949	18663	18629
50	60.6	105.1	6369	19912	18637	18603
51	64.7	122.2	7906	20085	18761	18725
52	61.4	108.1	6637	19933	18652	18618
53	63.0	111.9	7050	19976	18683	18648
54	62.5	110.8	6925	19959	18670	18636
55	62.7	111.4	6985	19964	18674	18640
56	61.1	106.0	6477	19980	18685	18651
57	60.9	101.1	6157	19858	18597	18565

[a] Q_p(net) calculated from equation (5)

[b] Net heat of combustion calculated from the equation given in Specification AN-F-28, Amendment 3, namely

Net Btu/lb = 4525 + 0.7070 Gross Btu/lb

Table 4. Effect of Time and of the Addition of Xylidine on the Aniline Points of Gasolines

Fuel No.	Initial Aniline Point, °F	Change with time, deg.F		Change with Addition of Xylidine, deg.F	
		6 weeks	10 weeks	1 percent	3 percent
2	136.4	0.0		-1.4	
3	123.8	.0		- .9	
4	146.5	- .2	-0.6	-1.6	-4.
5	135.0	- .4		-1.4	
6	122.8	+ .4		- .9	
7	108.3	- .7	-1.2	- .9	-3.1
8	131.5	- .9		-1.4	
9	127.2	-1.1		-1.3	
10	132.8	- .2		-1.4	
12	130.6	+ .2		-1.3	
13	127.0	- .5		-1.1	
14	132.3	- .5		-1.1	
15	120.0	- .4		-1.1	
16	115.2	-1.1		-1.1	
17	127.8	- .2		-1.3	
19	127.4	- .2		-1.4	
20	119.7	- .5		-1.1	
21	127.2	- .2		-1.1	
22	119.3	.0		-1.1	
23	115.9	- .4		- .9	
24	121.6	.0		-1.4	
25	120.9	- .4		-1.3	
26	120.9	-1.1		-1.4	
27	113.0	.0		-1.1	
28	127.0	- .5		- .9	
29	118.2	- .5		-1.1	
Average change		- .36	-.90	-1.19	-3.6

Table 5. Values of Q_p(net) for Various Values of the Aniline Point [a]

Aniline Point °F	Q_p(net) Btu/lb	Aniline Point °F	Q_p(net) Btu/lb	Aniline Point °F	Q_p(net) Btu/lb
90	18492	110	18662	130	18832
91	18501	111	18671	131	18840
92	18509	112	18679	132	18849
93	18518	113	18688	133	18857
94	18526	114	18696	134	18866
95	18535	115	18705	135	18874
96	18543	116	18713	136	18883
97	18552	117	18721	137	18891
98	18560	118	18730	138	18900
99	18569	119	18738	139	18908
100	18577	120	18747	140	18917
101	18586	121	18755	141	18925
102	18594	122	18764	142	18934
103	18603	123	18772	143	18942
104	18611	124	18781	144	18951
105	18620	125	18789	145	18959
106	18628	126	18798	146	18968
107	18637	127	18806	147	18976
108	18645	128	18815	148	18985
109	18654	129	18823	149	18993

[a] Calculated from the equation

$$Q_p(\text{net}) = 17727.7 + 8.494\ (\text{An Pt})$$

Table 6. Values of Q_p(net) for various values of the aniline point-gravity product [a]

Aniline Point-Gravity Product °Fx°API	Q_p(net) Btu/lb	Aniline Point-Gravity Product °Fx°API	Q_p(net) Btu/lb	Aniline Point-Gravity Product °Fx°API	Q_p(net) Btu/lb
5000	18484	7000	18681	9000	18878
5100	18494	7100	18691	9100	18887
5200	18504	7200	18700	9200	18897
5300	18513	7300	18710	9300	18907
5400	18523	7400	18720	9400	18917
5500	18533	7500	18730	9500	18927
5600	18543	7600	18740	9600	18937
5700	18553	7700	18750	9700	18946
5800	18563	7800	18759	9800	18956
5900	18573	7900	18769	9900	18966
6000	18582	8000	18779	10000	18976
6100	18592	8100	18789	10100	18986
6200	18602	8200	18799	10200	18996
6300	18612	8300	18809	10300	19005
6400	18622	8400	18818	10400	19015
6500	18632	8500	18828		
6600	18641	8600	18838		
6700	18651	8700	18848		
6800	18661	8800	18858		
6900	18671	8900	18868		

[a] Calculated from the equation Q_p(net) = 17992.0 + 0.09839 (AnPt-Gr)

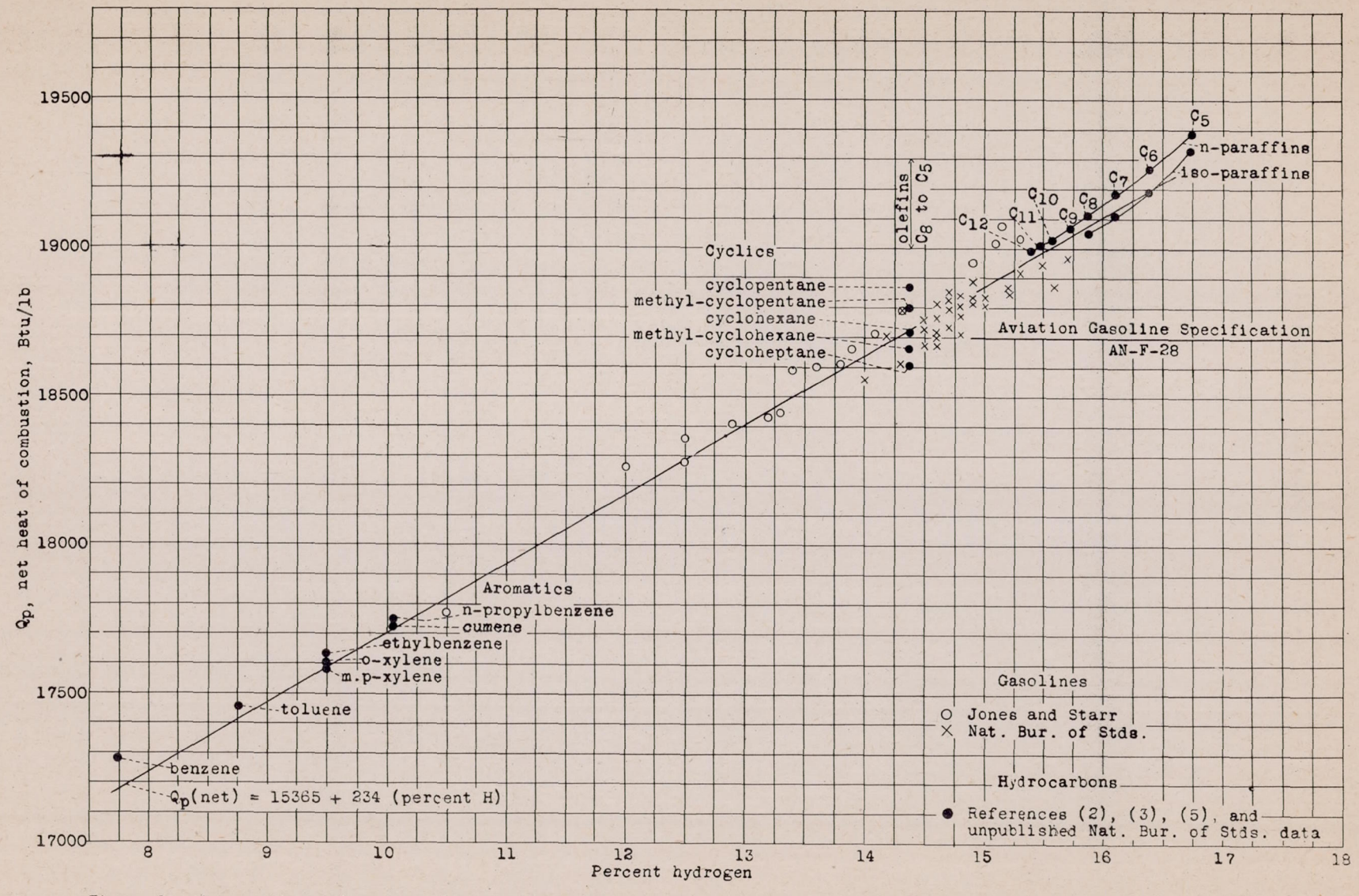

Figure 1.- Comparative data on gasoline and hydrocarbons; variation of net heat of combustion, Q_p at 25° C with percent H; Q_p(net) calculated from observed values of Q_v(gross) and percent H by means of equation (1).

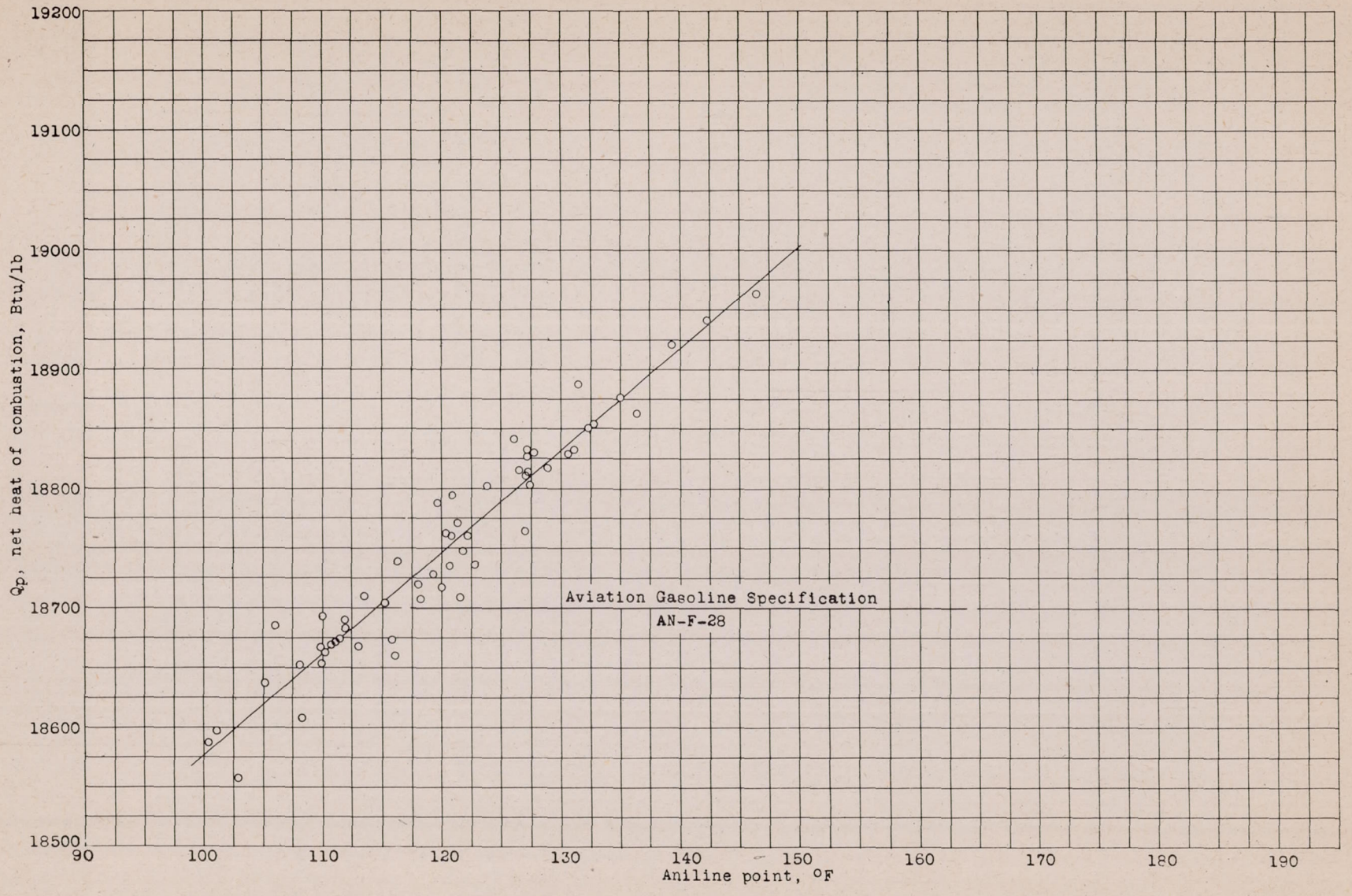

Figure 2.- Variation of net heat of combustion, Q_p at 25° C. with aniline point; Q_p(net) calculated from observed values of Q_v(gross) and percent H by means of equation (1) or (5).

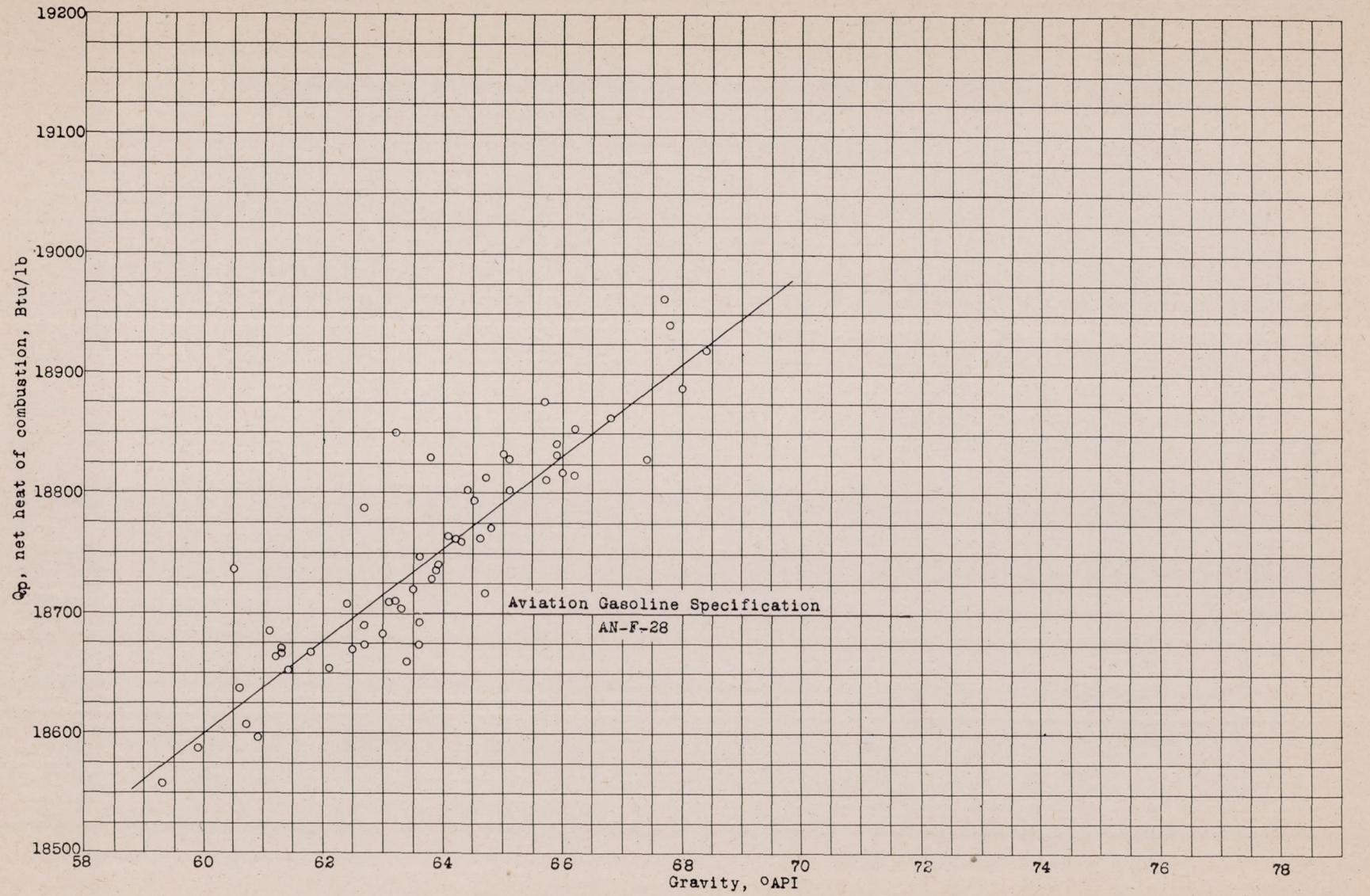

Figure 3.- Variation of net heat of combustion, Q_p at 25° C, with gravity; Q_p(net) calculated from observed values of Q_v(gross) and percent H by means of equation (1) or (5).

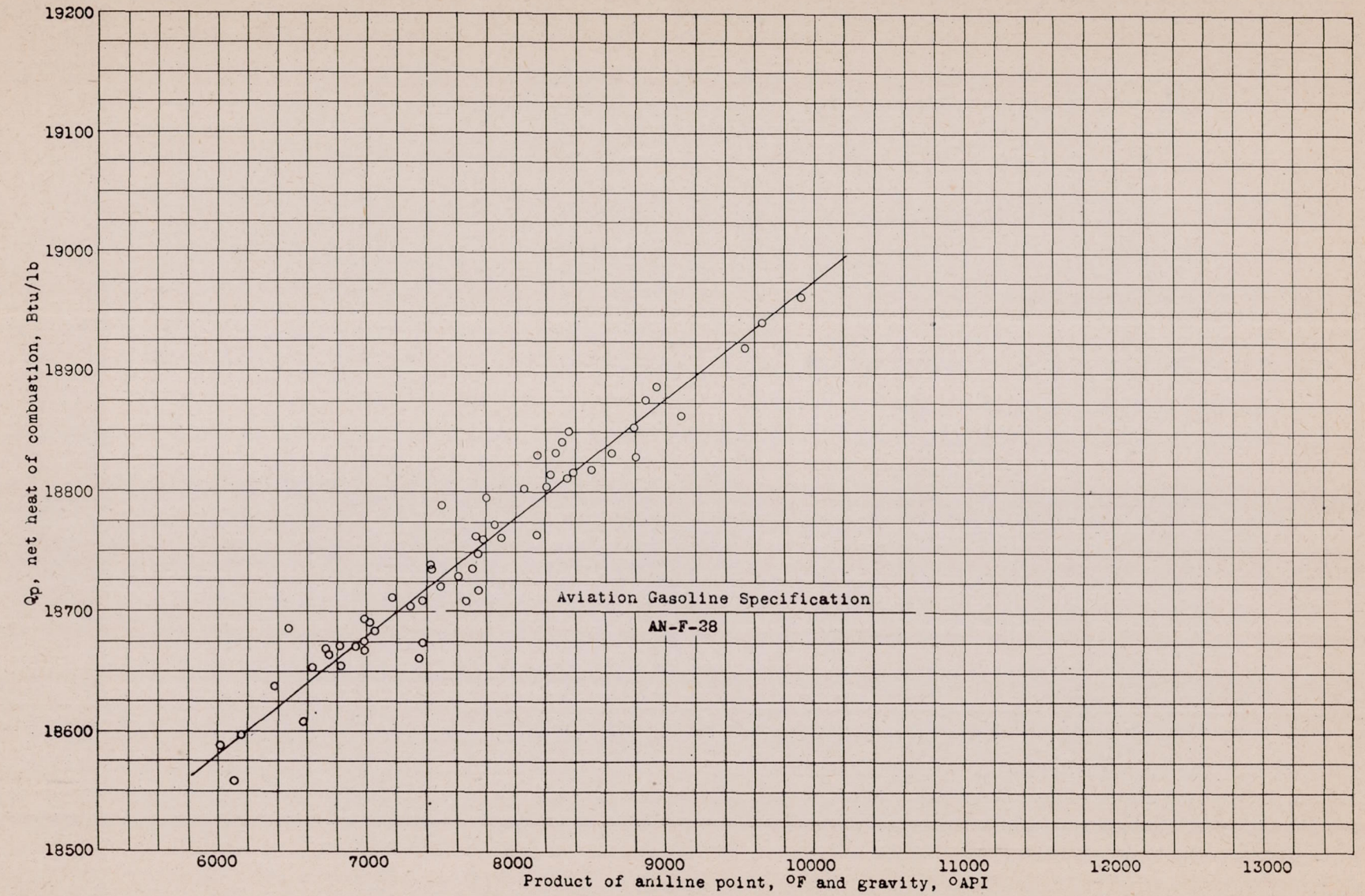

Figure 4.- Variation of net heat combustion, Q_p at 25° C, with aniline point-gravity product; Q_p(net) calculated from observed values of Q_v(gross) and percent H by means of equation (1) or (5).